Marine Stratocumulus Clouds: Turbulence-Raidation-Thermodynamics Coupling

ARM CLIMATE RESEARCH FACILITY

Research Highlight

Vast sheets of stratocumulus clouds are present over the eastern Pacific Ocean, off the coast of California to the north and off the coast of Chile and Peru to the south. When viewed from space through satellites, these clouds appear as bright cotton balls as they reflect about 60 percent of sunlight back to space, while the ocean surface looks dark as it only reflects about 2 percent of the sunlight back to space. By reflecting greater amounts of sunlight, these clouds effectively cool the Earth, making them important to be represented in the global climate model simulations aimed at predicting the future climate. The coverage of these clouds is intimately tied to the temperature and moisture (thermodynamic) structure of the lower atmosphere, called the boundary layer. This is the turbulence that transports moisture upwards from the ocean surface to form these clouds as well as the interaction between thermodynamics and turbulence. In this study, data collected was used for the Variability of the American Monsoon System (VAMOS) Ocean-Cloud-Atmosphere-Land Study Regional Experiment (VOCALS-REx) to study the interaction between the boundary layer thermodynamics and turbulence in stratocumulus topped boundary layers.

The instrumentation onboard the National Oceanic and Atmospheric Administration Ronald H. Brown ship during VOCALS-REx included a vertically pointing Doppler cloud radar, Doppler lidar, and radiometers. Balloon-borne radiosondes were also launched at regular intervals during the experiment to map the atmospheric thermodynamic and wind structure. Data from these instruments were combined to calculate the turbulence and thermodynamic profile of the lower atmosphere on hourly time-scales. Two distinct thermodynamic structures were observed during the study period: (1) Coupled – when the length scales of the processes within the boundary layer extended through its entire depth and (2) Decoupled – when the length scales of the processes at the cloud top and the surface extended until the middle of the boundary layer. We found the turbulence structure as characterized by the vertical velocity variance and skewness to be quite different for this thermodynamic distinction (Figure 2). The processes controlling the strength of the turbulence within the boundary layer include the radiative cooling near the cloud top, surface turbulent fluxes, and the change in winds with height within the boundary layer. When accounted for the magnitude of these processes in a parameter, called the velocity scale (w*), the changes in the turbulence structure for this distinction were able to be explained. When scaled by the velocity scale, the updrafts spanning through the entire depth of the boundary layer exhibited the same profile, both during coupled and decoupled conditions.

Data from the vertically pointing Doppler cloud radar and Doppler lidar during VOCALS-REx were combined to observe the turbulence structure of the entire stratocumulus-topped marine boundary layer. Convective velocity scale, which includes the effects of cloud top radiative cooling, surface fluxes, and wind shear was found to explain the changes in boundary layer turbulence for the coupled and decoupled thermodynamic distinction. Improved understanding of coupling between boundary layer turbulence and thermodynamics during stratocumulus cloud conditions will help scientists represent these clouds accurately in climate models.

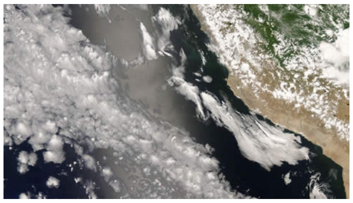

Figure 1. Visible satellite image of the South-East Pacific Ocean off the coast of Peru and Chile captured by Moderate Resolution Imaging Spectroradiometer (MODIS) onboard NASA's Aqua satellite on November 27, 2008.

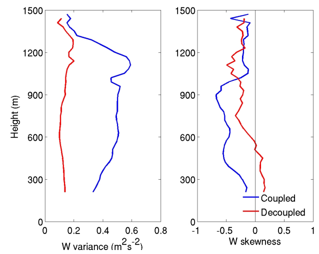

Figure 2. Profiles of vertical velocity variance (left) and vertical velocity skewness (right) calculated by combining data from the vertically pointing Doppler cloud radar and Doppler lidar onboard the R/V Ronald H. Brown.

Reference(s)

Ghate VP, BA Albrecht, MA Miller, A Brewer, and CW Fairall. 2014. "Turbulence and radiation in stratocumulus-topped marine boundary layers: A case study from VOCALS-REx." Journal of Applied Meteorology and Climatology, 53, 117-135.

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Working Group(s)
Cloud Life Cycle